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SYSTEM OF AUTOMATIC REGULATION OF REACTIVE POWER BY MEANS OF FUZZY LOGIC

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ABSTRACT

For increasing efficiency of distribution of electric energy the problem of indemnification of reactive-power by means of practical and theoretical researches is considered. On the basis of theoretical researches the algorithm of control of power of condenser by low sensitive to parametric indignations with the use of fuzzy theory is worked out.

Keywords: Distributive electric networks, reactive capacity, voltage, regulation of power, fuzzy logic.

1. INSTRUCTION

One of basic problems decided on the stage of design and exploitation of the system of power supply (SPS) of industrial enterprise is indemnifications of reactive power (RP) including some calculation of the compensated power, choice of method of indemnification, regulation and placing in plant.

For creation of economic work rejime of system of power supply in an enterprise and increase of efficiency distribution of electric power with minimum expenses on exploitation is expedient to carry out indemnification of reactive power with the use of static condenser units with the automatically udjusted power [3]. Application of condenser units with automatic udjusted power allows to decrease the losses of electric power in the elements of nets of the system of power supply, and also is one of the means of regulation of tension and upgrading of electric power.

On founding of data of research of SPS of the brickwork manufacture with the purpose of indemnification of RP it was defined that like the difficult system it functions at non determination conditions with different rejimes of operations of receivers of electric energy. Taking into account individuality of change of loading every consumer of electric power of the brickwork manufacture it is necessary to apply the centralized method of indemnification of RP, with placing of condenser unit in decreasing losts of the substation of the plant with connection of them on tires 0,4 кV. Power of the condenser unit is defined on the basis of calculation of loading the plant, and power of condenser battery is defined taking into account symmetric distribution them on phases and minimum level of indemnification of RP. At present the applied systems of automatic regulation of RP possess the large zone of insensitivity owing to preliminary tuning of them on the some value of the controlled parameter. In this connection, the error of the system of automatic regulation increases at regulation of power of the condenser unit [3], and possibility of creation of the economic rejime of operations of SPS and effective distribution of electric power goes down.

The aim of this article is development of the system and control of algorithm by power of the condenser unit of not sensitive to self-reactance indignations with the use of the theory of fuzzy sets [4-7].

II. STRUCTIVE SCHEME AND ALGORITHM OF THE SYSTEM OF AUTOMATIC REGULATION OF REACTIVE POWER

Structure of technical realization of the system of automatic regulation which provides rational control of RP in SPS of the investigated plant is given on the figure 1.

System automatic regulation consists: 1 - the loading unit; 2 - sensor of calculable block of reactive power; 3 - "Dynamics" (dynamics of change of reactive power); 4 - sensor of tension on the tires of loading; 5 - measure equipment of amount of switching accomplished for a day; 6 - fuzzyficater that is connected by means of 5, intended for transformation of clear signals to fuzzy sets; 7 - a table of linguistic rules (TLR), i.e. totality of fuzzy rules describing an unclear relation between the entry and output parameters of controller; 8 – defuzzyficater, where the got fuzzy value after defuzzyficater as clear controlling influence acts into the entrance of block of commutation (BC); 9 - BC.

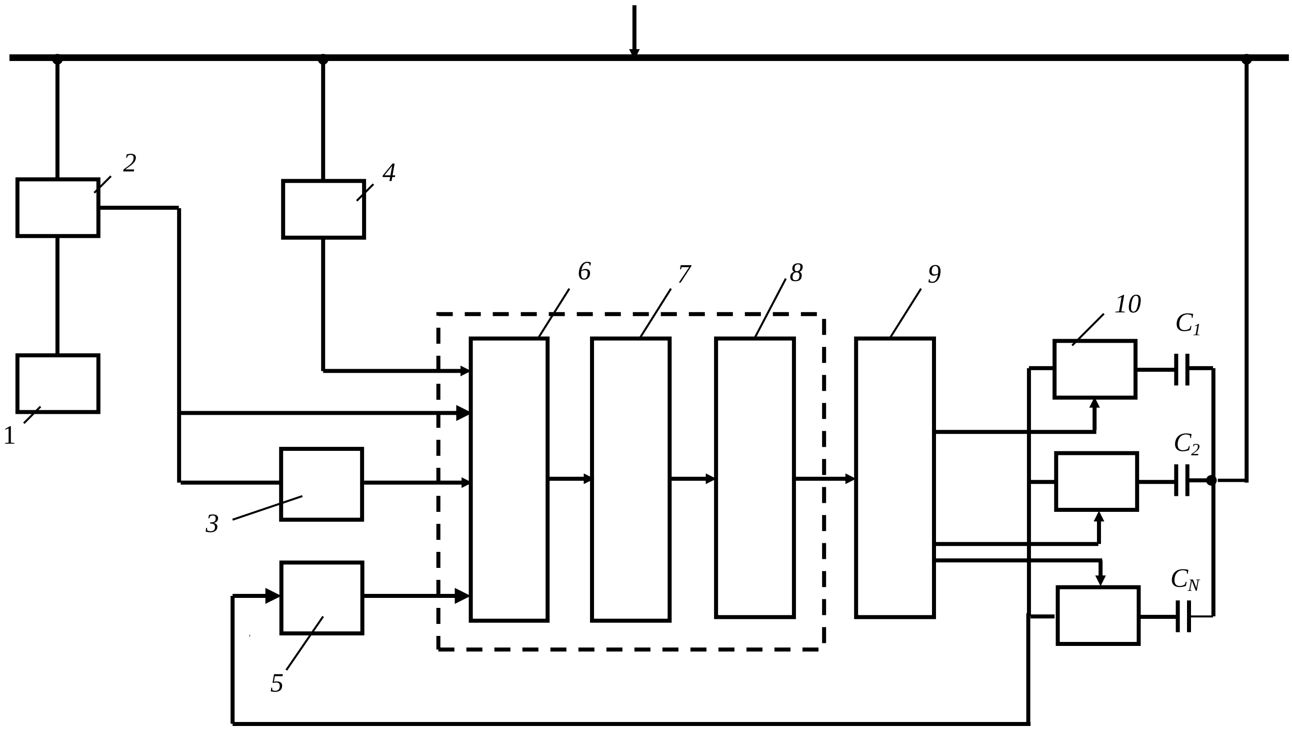

Fig. 1. Structure scheme of the system of automatic regulation (SAR) of reactive power

For SAR as fuzzy algorithm the algorithm of Mamdani was chosen. This algorithm is most often applied in practice, as it showed itself very well in many problems of control at rejime of real-time. Mathematically it can be described by the following of sequence of steps [2]:

- Fuzzy: there are degrees of truth for initial conditions of every rule

$$A_1(x_0), A_2(x_0), B_1(y_0), B_2(y_0)$$

Fuzzy conclusion: there are levels of "chopping" for initial conditions of each of rules:

$$\alpha_1 = A_1(x_0) \wedge B_1(y_0)$$
$$\alpha_2 + A_2(x_0) \wedge B_2(y_{0)}$$

where "^" is an operation of logical minimum (min) in the truncated membership function:

$$C_1' = (\alpha_1 \wedge C_1(z))$$
$$C_2' = (\alpha_2 \wedge C_2(z))$$

- 3. Composition: with the use of operation of max (designated as "V") association of the found truncated functions is produced. The date operation supports getting results of final fuzzy subset for the variable of exit with the membership function

$$\mu_\Sigma(z) = C(z) = C_1'(z) \vee C_2'(z) = (\alpha_1 \wedge C_1(z)) \vee (\alpha_2 \wedge C_2(z))$$

- Finally, a coercion to the clearness (for finding z_0) is executed for example by means of the Centerior method:
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$$z_0 = \frac{\int_\Omega z\mu_\Sigma(z)dz}{\int_\Omega \mu_\Sigma(z)dz}$$

III. MEMBERCHIP FUNCTIONS AND FUZZY TERMS

Membership functions used in the date article were mainly four kinds: triangle, trapezoidal, S and Z -figures. They are described by follows:

S – form. They are represented with two parameters – a, b:

$$\mu(x) = \begin{cases} 0, & x < a \\ \frac{x-a}{b-a}, & a < x < b \\ 1, & b < x \end{cases}$$

Z – form. They are represented with two parameters – b, c:

$$\mu(x) = \begin{cases} 1, & x < b \\ \frac{c-x}{c-b}, & b < x < c \\ 0, & c < x \end{cases}$$

Triangle. They are represented with three parameters – a, b, c:

$$\mu(x) = \begin{cases} 0, & x < a \\ \frac{x-a}{b-a}, & a < x < b \\ \frac{c-x}{c-b}, & b < x < c \\ 0, & c < x \end{cases}$$

Trapezoidal. They are represented with four parameters -a, b_1, b_2, c:

$$\mu(x) = \begin{cases} 0, & x < a \\ \frac{x-a}{b_1-a}, & a < x < b_1 \\ \frac{c-x}{c-b_2}, & b_2 < x < c \\ 0, & c < x \end{cases}$$

During work of controller on the algorithm of Mamdani in the distributive nets (maintenance of rejection of reactive-power in the rationed limits) [1]: on the entrance of fuzzy controller the calculated value of reactive power, dynamics of change of reactive power, calculated value of tension and most of switching for a day are given. From the exit of controller the values of linguistic variables of "Direct", "Delay" were taken off.

All entrance and output sizes are real values, as they are taken off from the real devices of the automatics. Further, in a controller, these parameters already will be transformed to the fuzzy values [5]. After the wearing-out of fuzzy rules, the got output variables again will be transformed to real form.

For working the fuzzy controller the following linguistic variables are used:

1. In the input of the controller (input variables):

- **Reactive power.** Fuzzy parameters of these linguistic variables are the following (fig. 2):
  Very small – Z-form membership function with parameters (0 0,05);
  Small – trapezoidal membership function with parameters (0 0,05 0,15 0,2);
  Middle - trapezoidal membership function with parameters (0,15 0,2 0,4 0,45);
  Large - trapezoidal membership function with parameters (0,4 0,45 0,85 0,95);
  Very large – S-form membership function with parameters (0,8 0,91 1).

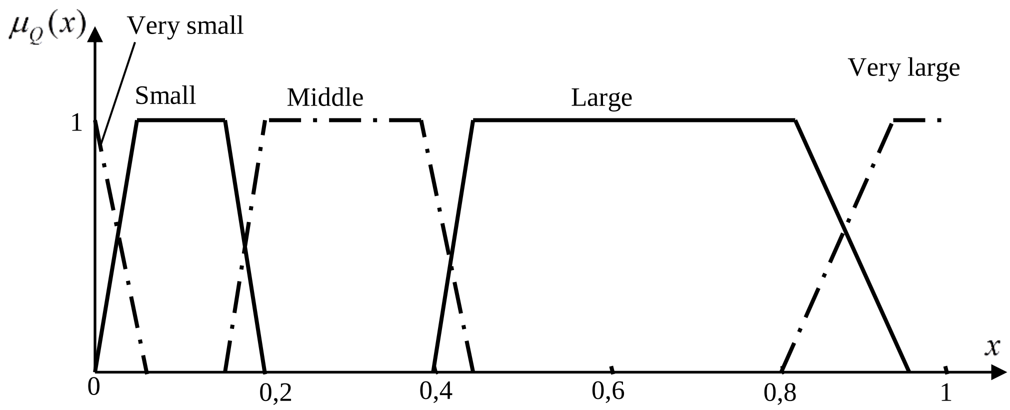


Fig. 2. Fuzzy values of variable of "Reactive power"

- **Dynamic.** Dynamic of changing reactive power (output of reactive power). The data of that variable (fig. 3).

Negative – Z-form of membership function with parameters (-0,5 0);
Zero's – membership function with parameters (-0,8 0 0,8);
Positive – S – form of membership function with parameters (0 0,5).

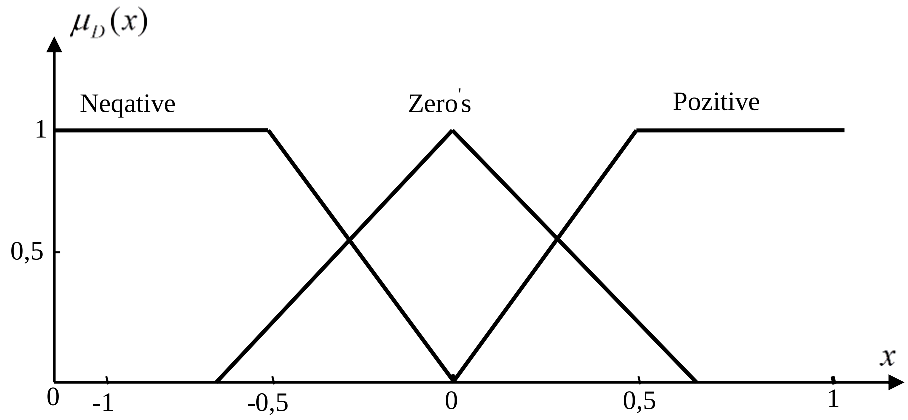


Fig. 3. Fuzzy value of the variable of "Dynamic"

Voltage. Voltage in the bus of loading. Fuzzy parameters of that linguistic variable are the following (fig. 4):

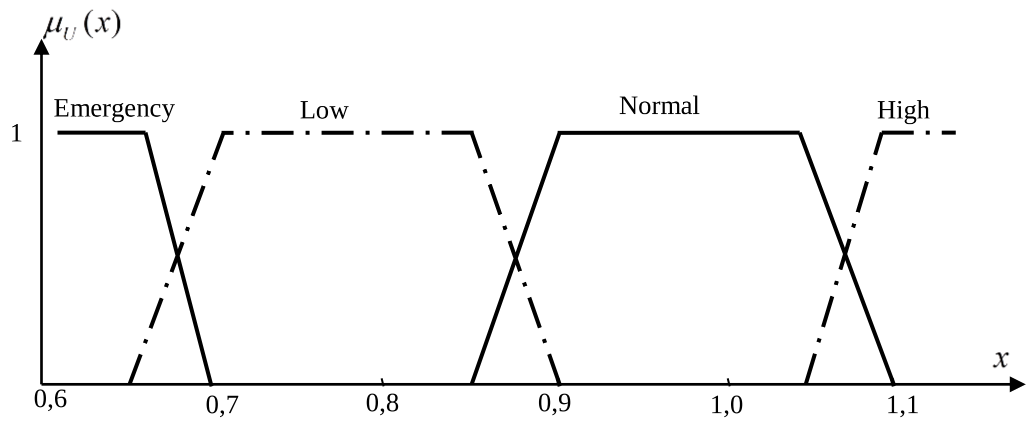


Fig. 4. Fuzzy value of the variable of "Voltage"

- **Emergency** – trapezoidal membership function with parameters (0,69 0,749 0,89 0,95);
  "Normal"- trapezoidal membership function with parameters (0,89 0,94 1,05 1,1);
  "High"- S-form membership function with parameters (1,05 1,1);
  "Low" – Z-form membership function with parameters (0,69 0,74).
- **Amount.** Amount of switching executed by the compensation equipment for a day. Value of that variable (fig. 5):

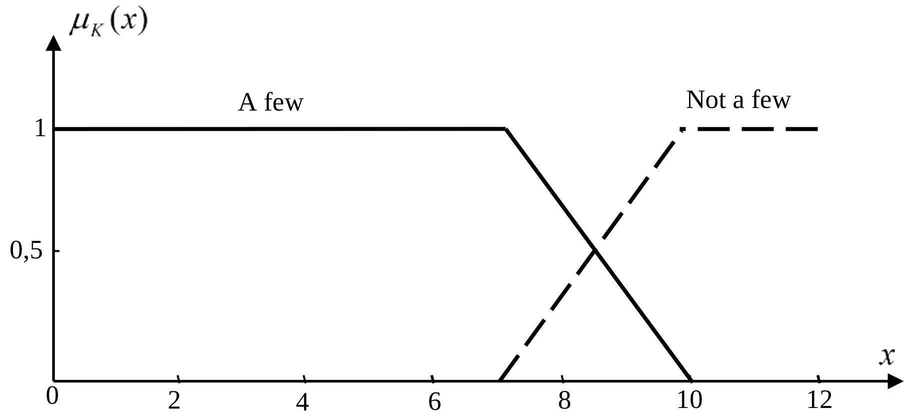


Fig. 5. Fuzzy value of the variable "Amount"

A few – Z-form membership function with parameters (7 10);
Not a few – S-form membership function with parameters (7 10).

2. From the exit of controller the values of the following linguistic variables (output variables) were taken off;

- **Direct.** Direction of the following switch. Value of the variable (fig. 6):
  Down - trapezoidal membership function with parameters (-1.5 -1.25 -0.75 -0.5);
  Up - trapezoidal membership function with parameters (0.5 0.75 1.25 1.5);
  Stay - trapezoidal membership function with parameters (-0.5 -0.25 0.25 0.5).

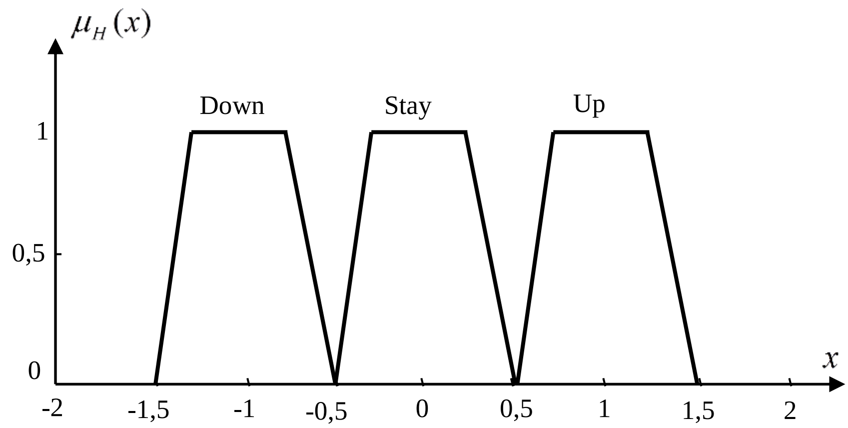


Fig. 6. Fuzzy value of the variable "Direct"

- **Delay.** Delay of time before switching. Fuzzy values of a variable (fig. 5b):
  Very Small – Z-form membership function with parameters (0 0.05);
  Short - trapezoidal membership function with parameters (0 0.05 0.15 0.2);
  Mean - trapezoidal membership function with parameters (0.15 0.2 0.4 0.45);
  Long - trapezoidal membership function with parameters (0.4 0.45 0.85 0.95);

Very Long - S-form membership function with parameters (0.8 0.9 1.1).

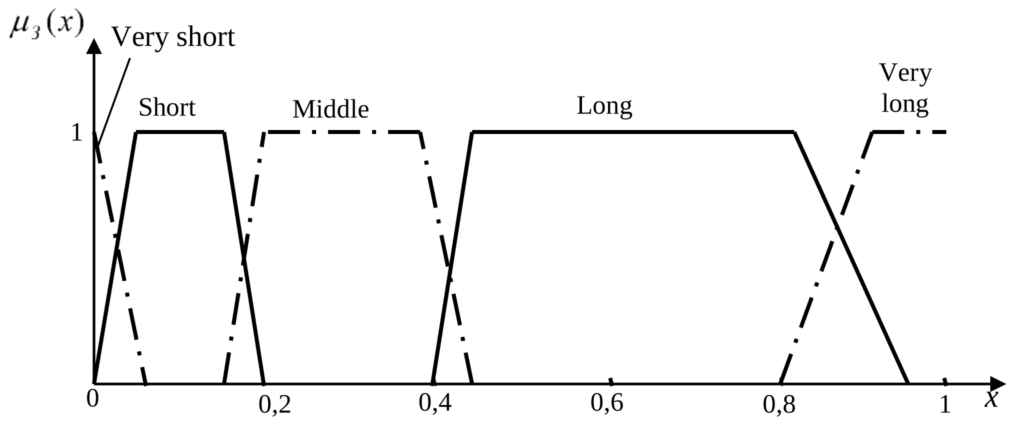


Fig. 7. Fuzzy value of the variable "Delay"

IV. SIMULATION RESULTS

By the given variables there were created 32 rules of fuzzy outputs for the date system. The got rules are given as:

1. If (Reactive power is Very small) (Voltage is normal) and (Amount is a few) and (Dynamic is Negative) then (Delay is very short) (Direction is To up);

2. If (Reactive power is Small) (Voltage is normal) and (Amount is a few) and (Dynamic is Negative) then (Delay is very short) (Direction is To up);

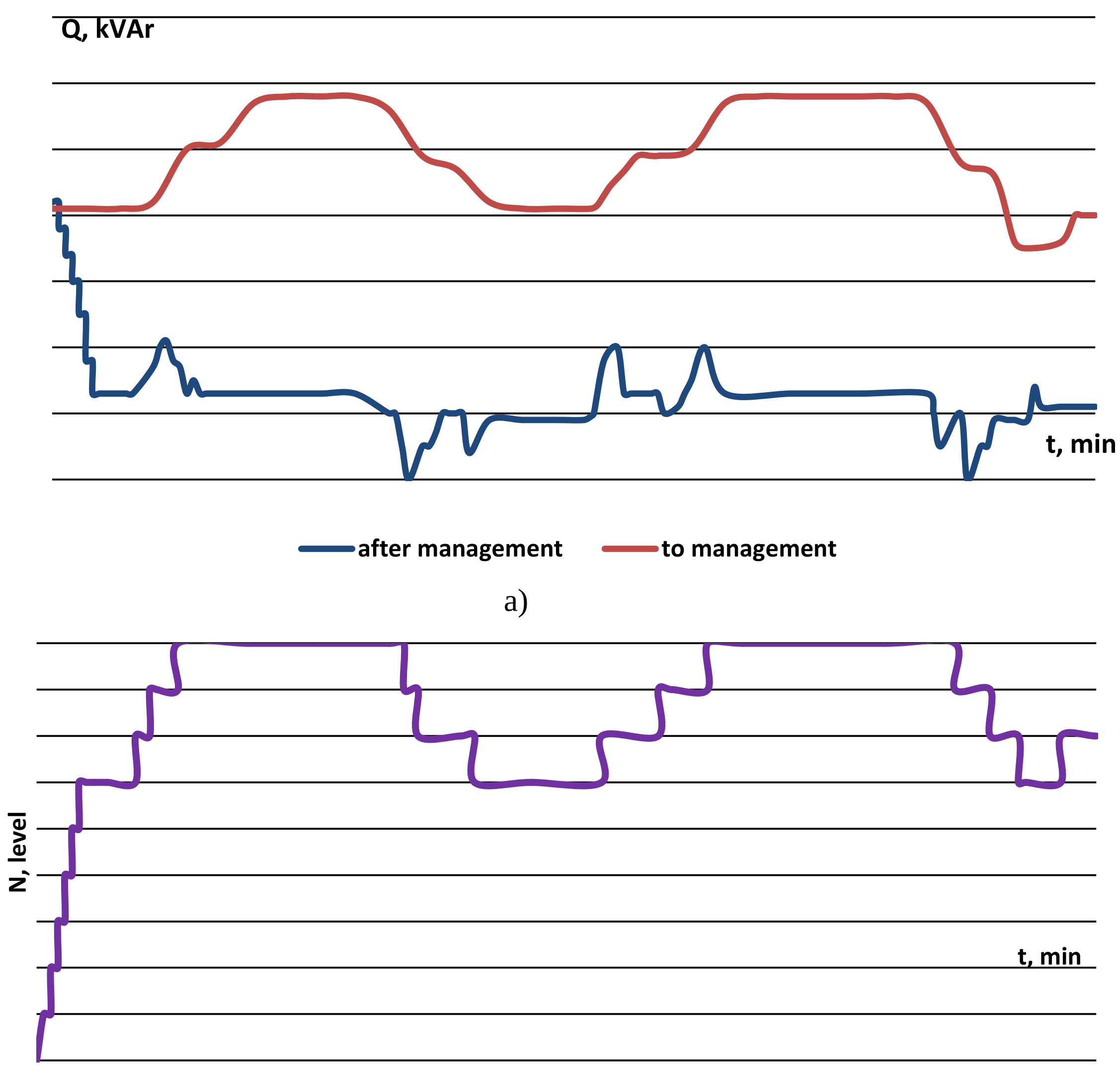
3. If (Reactive power is Mean) (Voltage is Emergency) and (Amount is a few) and (Dynamic is Negative) then (Delay is very short) (Direction is To up);

4. If (Reactive power is Large) (Voltage is Emergency) and (Amount is a few) and (Dynamic is Negative) then (Delay is short) (Direction is To up);

5. If (Reactive power is Very Great) (Voltage is Emergency) and (Amount is a few) and (Dynamic is Negative) then (Delay is short) (Direction is To up);

6. If (Reactive power is Mean) (Voltage is Emergency) and (Amount is a few) and (Dynamic is Positive) then (Delay is very short) (Direction is down).

During work of the researched model there were graphics of changing reactive power by time (fig. 8). First graphic, showed in the graphic, is represented as changing reactive power. The second graphic is represented as changing reactive loading. Third graphics are represented as spleens of working the condensation equipment.



b)

Fig. 8. The graphics of reactive loading, changing reactive loading (a) and spleens of working the condenser equipment (b)

V. CONCLUSIONS

It was considered fuzzy algorithm of regulation of reactive power by means of the algorithm of Mamdani. Regulation of reactive power was realized in the distributive nets for supporting reactive power from a consumer in the rationed limits. At researching work of fuzzy controller which functioned on the basis of the algorithm of Mamdani (at regulation of reactive power in the distribution nets of the factory) it was got that fuzzy algorithm produces less amount of switching as compared to traditional systems. That process provides rising efficiency of working equipments of switching steps of the condenser battery.

Device on the basis of fuzzy logic possess another important property - comparatively by simple expansibility. Addition of new properties, new functional possibilities for such devices are easily and undifficult. In case of occurring of necessarily to additional functions it is possibility to include them to work of fuzzy device.

It is possible to assert that devices on the basis of fuzzy logic are more preferable for regulation of reactive-power on the bus of consumers, than devices on the basis of ordinary logic. In this case regulation gets more quality, the amount of switching goes down, a condenser battery serves longer and probability of its refuse falls down.

REFERENCES

1. Graznov I. Y., Krivoshein A. A., Ivanov A. V. "Facilities of programming modern controllers", INFORMATION of VolgSTU, 2006.
2. Kruglov V.V., Dli M.I., Golunov P.Y. Fuzzy logic and artificial neural nets: educational manual-M: Publishing House of Physic - mathematical literature, 2001, 224 pages
3. Ilyashov V.P. Automatic regulation of power of condenser options. M. Energy - second edition.1979.-105 p.
4. Zade L. Concept of linguistic variable and its application to the acceptance of approaching decisions. Translation from English of N.I. Ringo. Under redaction of N.N. Moiseeva and S.A. Orlovskiy -M.: World, 1976.-165 p.
5. Poluyanovich M.N., Poluyanovich N.K. Microcontroller system of compensation of reactive power. A magazine is the Engineering announcer of Don, № 2 / volume 2 / 2007.
6. Yusifbayli N.A., Guliyev H.B. Intelligent Control System of Voltage Regimes in the Electrical Networks. IEEE PES Innovative Smart Grid Europe 2011, December 5-7 Manchester, United Kingdom.
7. Yusifbayli N.A., Guliyev H.B. Intelligent Voltage Regulation on Base of Fuzzy Sets Theory. The 12th International Conference on Pobabillstic Methods Applied to Power Systems. PMAPS 2012, 10-14th June 2012, Istanbul, Turkey, pp.447-453.