OPTIMIZATION OF POWER TECHNOLOGICAL PROCESSES IN ARTIFICIAL BIOENERGETIC AGRICULTURAL SYSTEM

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Abstract. The overwhelming majority of processes in agriculture may be described as "power technological processes" (PTP), i.e., the processes, which are based on transformation of the input energy at the beginning of the process into the products at the end of the process. The defining competitiveness factor of the made products is their energy content. The concept of an artificial bioenergetic agricultural system (ABAS) as the model of power content of agricultural production with due account of the biological character of objects under the impact of PTP is offered. Applied scientific theory of power saving in ABAS has been developed. On its basis it is possible to design and estimate the efficiency of power saving measures in ABAS; to substantiate the modes of PTP; to create the energy efficiency control algorithms for PTP.

Keywords: artificial bioenergetic agricultural system, power technological process, power consumption.

Introduction

Scientific, technical and innovative directions, which take into account an urgency of power saving, are of particular importance today for technological and technical modernization of agriculture branches. Agriculture is known to be a complex and peculiar object from the point of view of power supply. Specific functioning of agricultural sector is associated with the fact that the target objects of applied power technologies are biological ones – soil, plants, and animals. This defines the specific character of energy consumption and distribution in agricultural processes [1]. The purpose of this paper is to consider the optimization of an artificial bioenergetic agricultural system (ABAS) by the power consumption criterion, which is the competitiveness factor of the products made.

Multidimensional optimization of parameters of power technological processes (PTP), which take place in ABAS, is required to achieve the maximum effect of power saving measures.

The papers dealing with power economy are well known [2; 3]. A general model of biotechnical agricultural system has been offered by I.K. Khuzmiev [4]. The concept of an artificial power system (APS) of a consumer as the technical basis of energy flow and various processes management has been developed in the writings of V.N. Karpov [5]. In our opinion, the most comprehensive model of energy content of agricultural systems should take into account the presence of biological objects as produced items, production supporting tools and power processes.

Materials and methods

Fig. 1 shows the structure of ABAS as the set of the following objects and corresponding power technological processes (PTP).

1. An agricultural biological object (ABO) as the target of energy impact (plants, animals, and other biological objects). The purpose of the consumed energy is to execute the basic technological process of marketable goods production (PTP_B).
2. Climate control systems (CCS). Consumed energy maintains the living environment – heating, illumination, ventilation, air-conditioning, etc. (PTP_M).
3. Biological and technical means (BTM) to prepare the basic technological process of ABO treatment. Energy inputs here are used to perform certain supporting processes. (PTP_P).

Assumed borders of ABAS are the installation site of a fiscal metering system for all kinds of input energy and the point of outgoing inventory.

ABAS functions in the market environment. The energy market defines the current energy tariff rates. The market of technologies and the process equipment offer devices with different power efficiency η. The market of power-generating equipment provides a possibility to choose the suitable items. It is especially underlined that the market environment of ABAS includes the market of educational services. Its major task is to train the experts, who are competent in power-saving design approaches to technologies, process and power-generating equipment [6]. ABAS-made products enter the market of produce. Also it is necessary to take into account the power losses into environment.

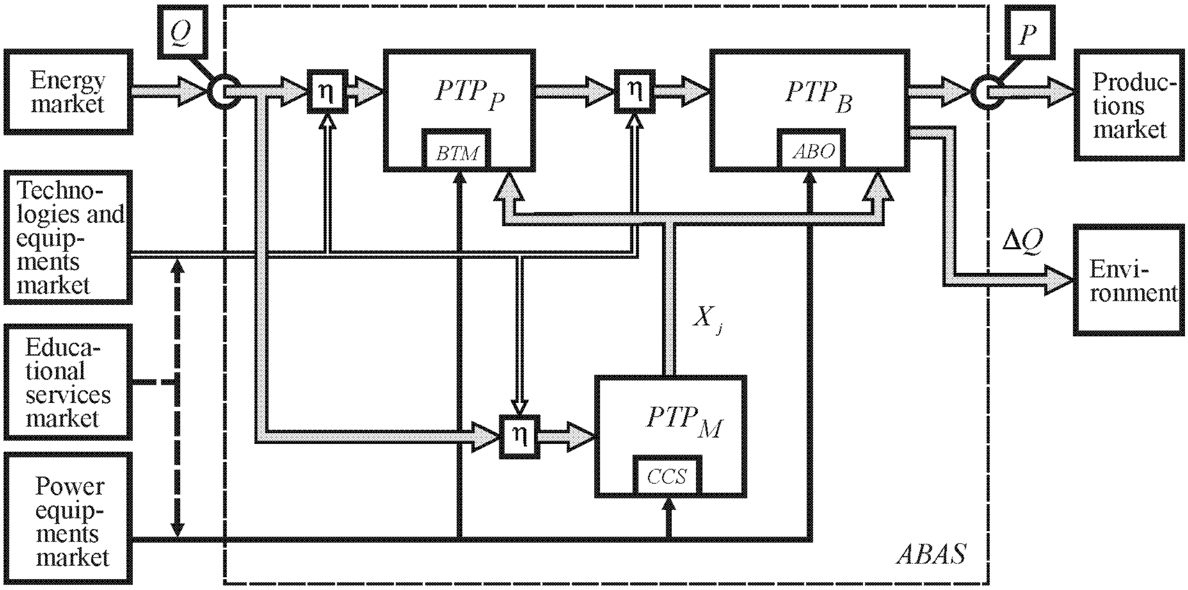

Fig. 1. **Structure of ABAS**

ABAS performance should be estimated by economic criteria. As a result of ABAS operation a certain quantity of products is produced, which are characterized by the vector components $\overline{P} = \{P_j\}$. An important economic indicator of ABAS is the profit Pr received from the output sales:

$$Pr = \sum_{j=1}^{n} D_j - \sum_{j=1}^{n} R_j \tag{1}$$

where D_j – j-th component of the income from sales;
R_j – j-th component of the costs associated with ABAS operation.

The income from sales of P_j-th product will be expressed as

$$D_j = C_j \cdot P_j \tag{2}$$

where $C_j = \{C_j\}$ – price of j-th product.

The production costs $\sum R_j$ include capital and operational costs to support ABAS operation.

When the annual profit Pr is considered, then $\sum R_j$ are specific annual expenditures, i.e., the capital costs and service life ratio for buildings and equipment, and annual operational costs (including the power costs). They depend on the technical and economic characteristics of separate ABAS blocks:

$$R_j = R_j^{(0)} + R_j^{(1)} X_j + R_j^{(2)} t_j X_j + R_j^{(3)} t_j \varepsilon_j Q_j \tag{3}$$

where $R_j^{(0)}$ – annual capital costs of X_j variable, independent of its intensity and time ;
$R_j^{(1)}$ – specific capital costs per unit of X_j variable;
$R_j^{(2)}$ – specific operational costs of variable X_j in unit time (without power costs);
$R_j^{(3)}$ – specific power costs for variable X_j in unit time;
ε_j – power consumption of j-th component;
Q_j – energy consumed to produce j-th component;
t_j – time setting of life-support X_j variable in the course of system operation;

The optimal operation mode of ABAS, which provides the maximum collected profit Pr, may be defined from the equation

$$\frac{\partial Pr}{\partial X_j} = 0 \tag{4}$$

under restrictions

$$X_{j_{\min}} \le X_j \le X_{j_{\max}} \tag{5}$$

where $X_{j\min}$, $X_{j\max}$ – minimum and maximum values of the optimized variable X_j.

The equation to search for optimum modes of PTP is

$$\sum_{j=1}^{n} C_j \frac{\partial P_j(\vec{X})}{\partial X_j} - \sum_{j=1}^{n} \frac{\partial R_j(\vec{X}, \vec{\varepsilon})}{\partial X_j} = 0. \tag{6}$$

Setting the requirement to ensure the minimum power costs (power saving condition), the equation to search for optimum modes of PTP may be presented as

$$R_j^{(1)} + R_j^{(2)} t_j + R_j^{(3)} Q \frac{\partial \varepsilon_j}{\partial X_j} = 0. \tag{7}$$

Then optimization of ABAS operation for each j-th component requires to observe the condition

$$\frac{\partial \varepsilon}{\partial X} = 0. \tag{8}$$

To find the modes, under which this condition is observed, specific features of power characteristics of PTP are to be considered.

For any typical PTP in agriculture it is possible to trace the following cause and effect chain: amount of input energy (Q) determines the process characterizing parameter (X), which determines the quantity of products (P). In any PTP energy losses (ΔQ) also occur.

The following characteristic features are typical of agricultural processes.

1. Effect of the law of optimum. According to this law, any factor X, which affects the living organisms, has only certain limits of positive influence. Both under and over exposure to the factor has a negative impact on the activity of living organisms. The response function of a living organism from the size of the factor P_X influencing this organism has more or less accurately expressed maximum.
2. Nonlinearity of functional dependence of the factor X value on the intensity of the power impact Q. In this connection to achieve similar increments of the factor X value it is necessary to apply the increasing increments of intensity of this impact. Such regularity is characteristic of the processes, the energy losses in which increase with higher power impact intensity.

The power balance equation of PTP is

$$Q = P + \Delta Q \big|_X . \tag{9}$$

Energy intensity of PTP by the factor X is

$$\varepsilon_X = \frac{Q}{P_X}. \tag{10}$$

The index "X" indicates that PTP is considered under the given value of the process characterizing parameter. The technological process of irradiation (TPI) of plants (as a special case of PTP) may be regarded as an example. Here, the energy consumed to create the radiating mode in a hothouse (Q) creates the irradiance in a hothouse (X), which determines the yields of the irradiated plants (P).

Fig. 2 shows (in relative units, under conditions of photoculture) the dependences between the quantity of the products made P and power consumption of TPI ε and the process characterizing parameter X (which in the given example is irradiance), i.e., P_X and ε_X function, and also the dependence of the parameter X on the amount of the input energy Q, i. e. , X_Q function.

The analysis of the presented graphs shows that with the increase of the consumed energy the value of irradiance grows, that (to certain limits) results in the growth of the yields of the irradiated plants. In this case the productivity optimum corresponds to the point "A" (maximum on the curve of yield dependence on irradiance P_X). However, from the point of view of power consumption, the optimal is the mode, which corresponds to the point "B" (minimum on the dependence curve of power intensity of TPI on created irradiance ε_X) [7].

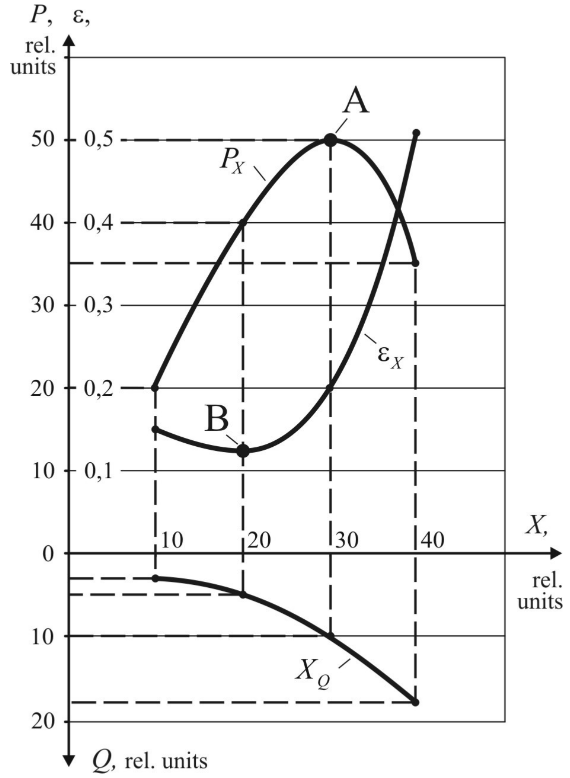

Fig. 2. **Characteristics of technological process of plant irradiation (TPI)**

Results and discussion

Thus, the task of energy saving management algorithm of PTP is to maintain the minimum value of power consumption at any given time. One way to fulfill this task is to find in pilot experiments the specified dependences, to define such a value of *X*, under which the power consumption is minimal, and to maintain during PTP the found value of *X*. However, in this case the disturbing influence on PTP is not taken account of. The method, by which the minimum value of power consumption is defined directly during PTP by the results of continuous monitoring of its parameters, seems more reasonable.

The scheme of an energy saving control system, which implements the algorithm under consideration, is shown in Fig. 3. The inlet of the system is the energy carrier flow *Q*, the outlet of the system is the flow of the products made *P*.

The system works as follows. The energy carrier flow *Q* is supplied to the inlet of the controlled object 3 (which may be any PTP) through the automated control block 1 and the metering block of energy carrier consumption 2. PTP results in production of some products, the amount of which as a flow of the output *P* goes through the metering block of productivity 4. At the outlet of the block 6 the value of the process characterizing parameter *X* is measured.

The block 5 with some interval, the length of which is defined by the rate of the change of dependences X_Q, P_x and ε_X, generates the time labels, according to which the energy carrier quantity supplied to the controlled object varies. In the blocks 7 and 9 the momentary values of the energy carrier consumption Q_i and the momentary values of the productivity P_i are calculated, accordingly.

In the block 8 the momentary value of the power consumption ε_i for the set time intervals ε_i under the current value of the process characterizing parameter *X* is determined. In the block 10 by the results of the analysis of power consumption dynamics to current time the forecast of the power consumption value for the following time interval ε_{i+1} is made. In the block 11 the decision on the need to change the quantity of energy carrier, supplied to the controlled object, is made. The corresponding signal is applied to the block of automated control of the object 1 [8].

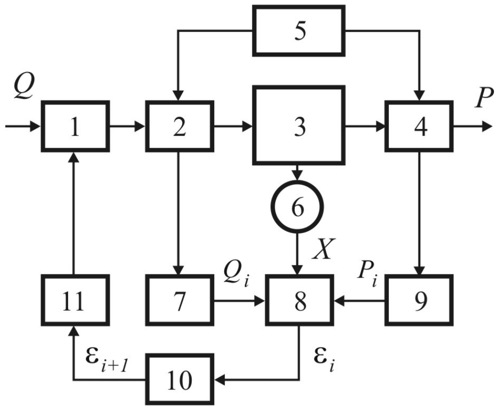

Fig. 3. **Energy saving control system scheme**

Conclusions

The concept of an artificial bioenergetic agricultural system (ABAS) as a set of an agricultural biological object, climate control system, biological and technical means to prepare the basic technological process is offered. The groups of power technological processes (PTPs), which correspond to separate ABAS components, are identified - basic, maintaining and supporting. Mathematical optimization of ABAS efficiency has shown that the power saving task may be accomplished by decreasing of pthe ower intensity of PTPs in the system.

The analysis of typical PTPs in agriculture demonstrates that universal laws of agricultural biological object functioning are the law of optimum and the law of nonlinearity of functional dependence of the factor X value on the intensity of the power impact Q. Joint action of these laws provides the possibility to formulate an optimizing task – to maintain the minimum power consumption of PTP.

Application of the above system will allow ensuring the power saving in PTP at simplicity of technical realization of the system, increase of the degree of autonomy of its functioning, possibility of control defining a current of process of internal parameters and accuracy of management with the system.

The above-considered general methodology of estimation and optimization of a bioenergetic agricultural system should be regarded as the applied theory of power saving in agricultural PTP.

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